International Journal of Civil Engineering and Technology (IJCIET)
Volume 7, Issue 1, Jan-Feb 2016, pp. 260-273, Article ID: IJCIET_07_01_022
Available online at
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=7&IType=1
Journal Impact Factor (2016): 9.7820 (Calculated by GISI) www.jifactor.com
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

THE EFFECT OF IMPROVEMENT SURROUNDING SOIL ON BORED PILE FRICTION CAPACITY

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ABSTRACT

There is very close relation between the pile capacity and surrounding soil conditions. In cohesionless soil the bored pile effected on surround soil byloosen , deposits through a combination of pile volume replacement and exist of pile case used for installation of bored pile. .the pile foundation usually designed to exceed the weak soil to the firm deposit .in this study improvement of the weak soil surround the pile and observing the effect of improvement on pile capacity for bored pile. The improvement soil surround pile model was design to be as one block and kept this block will effect noticeably on pile load capacity results. the improvement suggested in this study is compacting and replacement for surrounding soil . for this purpose testing program prepared by selection two types of sand soil one as the origin soil and the other as improving soil (soil will be compacted and replace surround pile model) . pile model prepared for this purpose is consist of reinforcement steel bar covered with cement mortar ,50 kN automatic electromechanical compression machine was used for testing load- settlement test on pile model. testing procedure includes changing the diameter of compacted soil around pile model and execute the load settlement test and compare the results with each other and with results obtained from Hansen equation.

Key words: Compaction, Pile Model, Pile Model Capacity, Load-Settlement curves, Hansen Equation, Angle of Internal Friction, Cohesion, Adhesion

Cite this Article: Mohammed M. Salman and Prof. Dr. Abdulaziz Abdulrassol Aziz, The Effect of Improvement Surrounding Soil on Bored Pile Friction Capacity, *International Journal of Civil Engineering and Technology*, **7**(1), 2016, pp. 260-273.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=7&IType=1

1. INTRODUCTION

Evaluation of pile bearing capacity is still a subject of many researches. Several researches mentioned that, the calculated pile bearing capacity by conventional methods often gives poor agreement with the load test results (Kraft, 1991; Randolph et al., 1994,).The ultimate bearing capacity and settlement of a pile depend mainly on the density index of the sand.. The soil characteristics governing ultimate bearing capacity and settlement, therefore, are different from the original characteristics prior to driving this fact, in addition to the heterogeneous nature of sand deposits, makes the prediction of pile behavior by analytical methods extremely difficult. For relatively long flexible piles which are commonly used for foundation of offshore structure .pile shaft resistance represents the major component in total pile capacity when the pile are subjected to cyclic loading. failure can occur at very low load level in some sand soil (chan and hanna, 1980).Compaction is the process of increasing the density of a soil by packing the particles closer together with a reduction in the volume of air; there is no significant change in the volume of water in the soil. In general, the higher the degree of compaction the higher will be the shear strength and the lower will be the compressibility of the soil. The dry density of a given soil after compaction depends on the water content and the energy supplied by the compaction equipment (referred to as the compactive effort) (GRAIC, 2004).

There are many researchers and projects consulta- tive studied the replacing all soil for specific depth to improve the soil strength and liquefaction resistance like (Risk of the ground liquefaction in the Fraser Delta / British Columbia: Protection of a liquid gas tank by means of vibro replacement (Chambosse, 1983Khalifa Bin Zayed National Stadium, Abu Dhabi: Vibro stone columns around bored piles (2009**)** Soil improvement by means of Vibro Compaction: Fort Calhoun Nuclear Station(Fischer et al., 1972),) in this study replacing and compacting only the surrounding studied.(SONDERMAN,2011)

2. LITERATURE REVIEW

Skin friction of pile is controlled by coefficient of earth pressure and angle of adhesion δ between soil and pile. The value of K_s is critical to the evaluation of the shaft friction and is the most difficult to determine reliably because it is dependent on the stress history of the soil and the changes which take place during installation of the pile (Tomlinson, 1994)] boring process will tend to loosen the soil and decrease the angle of internal friction which in turn will lead to reduce the horizontal stress.

The value of δ may be measured in interface shear test for the particular pile material, but for the cases where the test is not available, it can be assumed equal to $\o_{c.v}$ (Fleming et al., 2008).The shear strength of the sandy soil mainly depends on angle of internal friction and this friction angle is highly dependent on stress level.

There is a problem arise with question 'did this variation have a great effect on bearing capacity' and ' if it did, what value of friction angle should be used for safe and economical design'. Many researchers studied the variation of friction angle of sand with stress level. Results of previous researchers shows that the load - settlement relations approximately have the same trend shape for both relative densities of sand (dense and medium sand) with all embedment ratios. When the loading process on the pile is starting, the pile settlement response seems to be very close to linear relation due to small settlement value. After this stage and with continuing loading process, the non-linear behavior of soil appears and provides a visible curvature as soil elements start to fail causing a significant increase in rate of settlement and provide a hyperbolic shape for load - settlement relation It can be seen from load - settlement curves for both dense and medium sands that the punching type failure is control for all stresses ranges and as embedment depth increases the capacity of piles increases for all range of stresses(AKOOBI,2012) the end bearing capacity is much higher than the shaft resistance in laboratory dimensions and the shafts resistances contribution in the total capacities for piles are very low. when lengths of piles increase the end bearing, shaft, and total capacities are increased.

The increase in end bearing with length gives an indication about increasing in bearing capacity factor as embedment ratio increase. The reason that the mobilized end bearing capacity is much higher than shaft resistance may be attributed to high friction angle mobilized in such low stresses and the dependency of end bearing capacity of piles on angle of internal friction In case of higher stresses range the mobilized end bearing capacity start to become less than shaft resistance and the difference between them increase as lengths of piles increase. This behavior also attributed to the reduction of internal friction angle due to increasing in stress level in such dimensions. Same behavior can be noticed for medium sand. In low stress level, the end bearing capacity is larger than shaft resistance and as stress level increases, the difference between end bearing and shaft resistance decreases until shaft resistance becomes larger than end bearing. Itcan be noticed also, that the end bearing capacity of medium sand is less than the end bearing capacity of dense sand by a significant amount but the shaft resistance of dense sand is higher than the shaft resistance of medium sand this is attributed to the difference between angles of adhesion between pile and surrounding soil.

From the observations discussed above, it can be concluded that the stress level has a significant effect on end bearing capacity and insignificant effect on shaft resistance and the care should be taken in extrapolating the results from a model pile in small scale dimensions (low stress level) to field dimensions (high stress level) and for such extrapolating a stress level factor should be used for safe and economical design for pile in sand. Pile dimension have significant effect on pile capacity increasing the pile length means more stress generated at the pile interface along its length and will lead to increase pile capacity. Also, increasing the diameter of pile means increasing in the surface area of the shaft contact with the surrounding soil which in turn will lead to increase in the shaft resistance. In addition, increasing the

diameter of pile means more end bearing resistance area of pile. (AKOOBI, 2012)Improvement of horizontal bearing capacity by composite ground foundation method The composite ground foundation is a new type of foundation that remarkably improves the horizontal bearing capacity by considering the mechanical interaction effect of the improved ground and pile which are installed as one body. Traditionally, the ground and foundation structure are considered as independent models, for example, in the case of pile foundation, the load resistance characteristics of soft ground and pile are considered independently in the analysis.

New construction methods are being studied in order to restrain horizontal displacement and lessen the number of piles, and consequently, reduce the construction's total cost, using Deep-Mixing-Method (DMM) which reinforces ground resistance by pouring cement in peripheral ground. The "composite ground foundation method," that is defined herein, is a foundation practice which expects positive effect of interaction between the improved ground in-situ and the existing pile(MAEDA,2007).The Bearing capacity of the model pile increases with increasing the Rate of loading .The relationship between the compressive Bearing capacity and the loading rate can be represented by a Straight line on alog-log plot(AL-MAHADIB,1999).depending on previous studies we shall replacing surround soil around pile and compact it then drive the pile model with changing the diameter of area improved with compaction and length of pile model drove in soil and observe the results of load-settlement for each case separately

3. EXPERMANTAL WORK

Many steps adopted to perform the testing program started with soil tests to determine soil parameters for two types of soil. The soil Characteristics shown in table (1) and (2) the soil types divided to two types the first considered as natural soil and other as replacing soil around pile model which will be compacted. chemical test was made to understand the effect of chemical components on soil behavior after compaction .The pile model shown in fig (2-c) connect to compression device as shown in fig(2-a) .the embedded length of piles was located to embedded it into soil(100,150) mm. The container filled with soil (type 1) ,with existing of pile model to specific length the pile model fixed at that length by screw as shown in fig (2-b).Then the compression device adjusted and operated for a constant rate of settlement (1.27 mm/min) (strain control test).(ALI.A.M,2012) performed the bored pile as existing model at specific length then the model embedded into sand as shown in fig (2-b)depending on that pile model will be existed and soil filled the container the container are manufactured according specific determination with dimensions (350*350*350) mm . And because of setting of the device on constant rate of settlement the pile will be loaded by jacking it by compression device arm movement.

The results obtained are considers as original case (without improvement).soil (type2)was used for improve the surrounding soil by compacting it by steel bar and adding water according to amount of optimum moisture content obtained from proctor test(11.8%) maximum dry density was equaled to(18.5 kN/ m^3) for soil type (2).(p. v. c pipe)longitudinally separated from one side this splitting is to make it easier to extract it after compacted surrounding soils because of the existing pile model. this pipe used as case to contain compacted soil around pile model(casing pipe)with existing of pile model As shown in fig(2-e)with different diameter for

improvement soil around pile model. The soil with optimum moisture content is adding by equal layers (3cm) for each layer, compacted by constant number of blows for each layer (blows according to casing pipe diameter). The casing pipe was pulled at same time of compaction ,to prevent the adhesion between the pipe and compacted soil .and to ensure the interlocking between the compacted soil and soil around.-this operation is repeated for three different diameter of improvement (43,73,100 mm)-After compaction of improvement soil (type 2),pile was settled at desire length as previously mentioned .the device operating and load-settlement reading appearing on device display this reading using to plot load-settlement curves which using to estimation the pile capacity by two tangent method.

Table1 Soil Type (1) Characteristics

No	Index property	Value
1.	Specific gravity (Gs)	**2.61**
2.	D_{10} (mm)	**0.116**
3.	D_{30}(mm)	**0.211**
4.	D_{60}(mm)	**0.337**
5.	Coefficient of uniformity(C_u)	**2.91**
6.	Coefficient of curvature($C_{c)}$	**1.14**
7.	Maximum dry unit weight (kN/m^3)	**17.42**
8.	Minimum dry unit weight (kN/m^3)	**14.20**
9.	Maximum void ratio	**0.803 880**
10.	Minimum void ratio	**0.469**
11.	Angle of internal friction (ϕ) in loose case	**29**
12.	C VALUE	**0**
13.	Soil classification (USCS)	**SP**

Table 2 Soil Type (2) Characteristics

No	Index property	Value
1.	Specific gravity (Gs)	**2.54**
2.	D_{10} (mm)	**0.096**
3.	D_{30}(mm)	**0.231**
4.	D_{60}(mm)	**0.409**
5.	Coefficient of uniformity(C_u)	**4.26**
6.	Coefficient of curvature(C_c)	**1.36**
7.	Maximum dry unit weight (kN/m^3)	**17.56**
8.	Minimum dry unit weight (kN/m^3)	**14.03**
9.	Maximum void ratio	**0.776**
10.	Minimum void ratio	**0.418**
11.	Angle of internal friction (Ø) in dense case	**44.4**
12.	(C) VALUE	**0**
13.	Soil classification (USCS)	**SP-SM**
14.	Maximum density due to compaction (kN/m^3)	**18.5**
15.	Optimum moisture content	**11.8%**

Table 3 Chemical Tests for Soil Type (2) (Al Ekhidhar Sand)

PH	SO_3	TSS	Organic	Gypsum
8.16	3.2	6.0	6.2	6.9

4. RESULTS AND DISCUSSIONS

The following results are obtained from

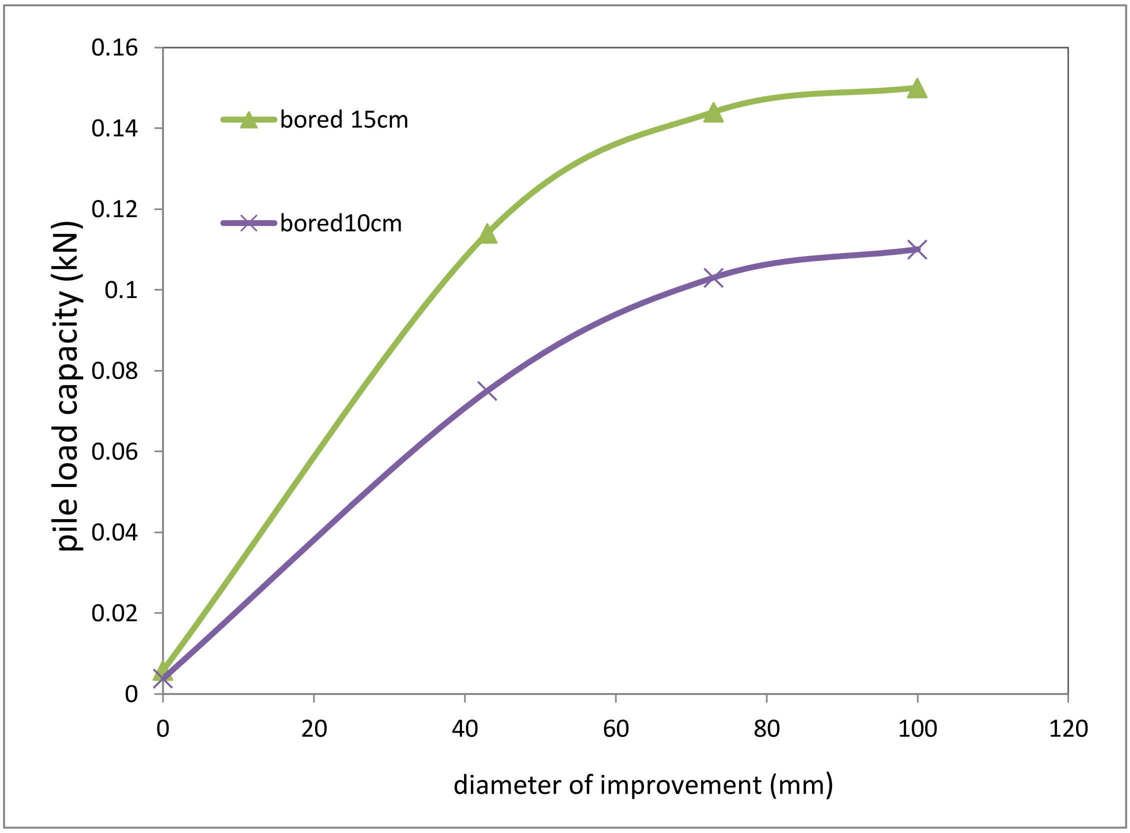

Figure 1 The relation between pile load capacity and diameter of improvement

From previous relationship we can conclude that the effect of compaction appear clearly when the structure of compacted soil which surround pile still coherent, for that reason the compaction is more effective in case of bored pile that's belongs to compaction of surrounding soil performed in presence of pile model . that lead for more interfering between the pile model and compaction lead for more interlocking between soil particles which causing increase cohesion of soil and make soil block firmer. Stability of this structures its most effective parameter in rise of pile load capacity. And compaction in presence of pile model and withdraw casing pipe will lead to interfering between soil compacted block and around soil . Although this block consider to be firm and Coherent but it's still a brittle structure and that's what explain curves down after reach ultimate pile load capacity in bored pile case. The figure(1) give indication that in case (bored) that the difference between two length (100 and 150)mm is almost constant this belongs to the constant difference of length lead to decrease Perimeter area and that's lead to decrease in friction force. The pile load capacity increase in case of bored due to the behavior of compacted soil block in case of bored pile it worked as one block as shown in figure (3-a) and figure (3-b) The keeping of compacted soil block as one body and the weak support of soil surround that block due to loose density all this made this block behave as one block and that's mean more friction force and more tip load. All these reasons lead to increment in pile load capacity Soil block in bored case keep it structure constant approximately as shown in figure (3-b) From previous tests results clear observation on the route of

compaction effecting on pile load capacity we also connect it with the distance from pile face to the end of improvement area and related to pile model diameter as following:

1. (43mm) distance equal to (D) from face of pile.
2. (73mm) equal to (2D) from face of pile.
3. (100mm) equal to (3D) from face of pile.

For the previous test results we notice that for the both cases (bored-driven) its seem to be that the best choice and economic for improving surround soil is at distance (D) pile face at this distance the pile load capacity increased as following :

1. For pile length (15cm) bored case (0.0058k N normal case to 0.114kN)
2. For pile length (10cm) bored case (0.0038k N normal case to 0.054kN).

The increments in pile load capacity beyond a distance (D) will be lighter compare to the first increment occur. The settlement also increases due to improvement of surround soil. Hansen equation was used to compare the results with experimental work and if obevious that there is different between the equations results and experimental work observed. Because the effect of improvement will decrease with increase of diameter of improvement around pile model this not appear in equation. For the case of improvement (73 mm) the skin friction of whole compacted soil block with length (15 cm) has been equal (0.0342 kN) if it is added to the tip load resistance for case of (43 mm) the result would be (0.139 kN) and this value approaching to the results obtained from load-settlement test which is equal(0.144 kN). Same applied on (100mm) length of pile model and for (100 mm) diameter of improvement. From previous we conclude that the most effected range of improvement inserted by limited of (43 mm) .the increment in improvement diameter around pile will cause increment in skin friction of compacted soil block with surrounding soil with slight increment in tip load resistance.

5. CONCLUSIONS

Compaction will effect on soil parameters and will lead for increase in cohesion and soil interlocking which results increasing in soil strength. Compaction effect on soil surrounding the pile and soil under tip. the case installation of replacing soil surround pile will reduce the angle of internal friction .while it increase under tip because of compacting blows. The effect of compaction appears obviously when compacted soil block surrounded pile still as one structure as it observed in bored case. The effective range of improvement inserted in the close limits around pile model in this study (approximately (D) from face of pile) which is cause increment in tip load resistance for soil block (model –compacted soil) any increase beyond this limit will cause slight increment in pile load capacity due to increment in skin friction of soil block with soil contact it .The soil under pile model tip will not compacted at same degree of soil under replacing soil surrounding pile. This create a weak zone under pile model tip

RECOMMENDATIONS

1. Determine the best choice for improvement and most economic selection and determine reality for future studies on prototype.
2. studying effect of compaction surrounding soil on pile tip
3. studying the pile installation effect on soil improvement
4. Studying the chemical material content on compaction results.
5. Studying the effect of improvement surrounding soil on pile capacity with existing of water.

Table 4 Percentage of increment for pile capacity for each case

Type	Length (mm)	Improvement (D) Percentage of increment%	Improvement (2D) Percentage of increment %	Improvement (3D) Percentage of increment %
bored	150	1865	2382	2486
	100	1321	2610	2794

APPENDIX

Figure 2 (**a**-compression machine, **b**-embedded pile model to desire length **,c**-pile model, **d**-soil block in whole around soil **,e**- installation on case pipe around pile model and compact surround soil)

Figure 3 (**a-**compacted soil with pile model as one block, **b-** soil block after extracting pile model)

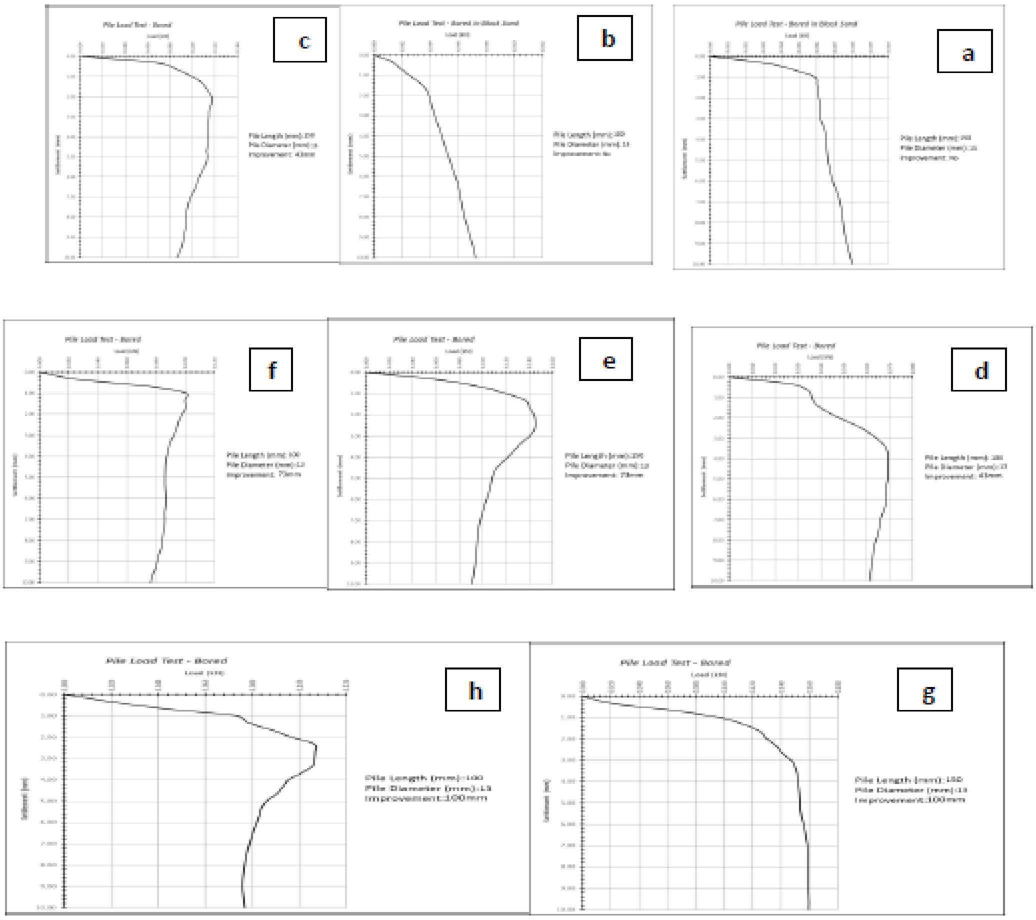

Figure 4 The load –settlement curves (**a-** with out improvement length =150mm **b-** with out improvement length =100mm **c-** with improvement diameter (43mm) length =150 mm **d-** with improvement diameter (43mm) length =100 mm **e-** with improvement diameter (73mm) length =150 mm **f-** with improvement diameter (73mm) length =100 mm **g-** with improvement diameter (100mm) length =150 mm **h-** with improvement diameter (100mm) length =100 mm)

Table 5 of pile load capacity results of experimental work summary due to improve surrounding soil

Type	Length (mm)	Without Improvement pile load capacity (kN)	Improvement diameter (43 mm) pileload capacity(kN)	Improvement diameter (73 mm) pileload capacity (kN)	Improvement diameter (100 mm) pileload capacity (kN)
bored	150	0.0058	0.114	0.144	0.150
	100	0.0038	0.075	0.103	0.110

Table 6 show the details of pile capacity terms for (15 cm) according to use Hansen equation

Case for 15cm length	Pile load c by experimental (kN)	Pile load capacity by equation (kN)	Skin friction of pile model with block(kN)	Skin friction of block with surround soil(kN)	Tip load for whole block (kN)
(43 mm) diameter improvement	0.114	0.116	0.328	0.0201	0.0958
(73mm) diameter improvement	0.144	0.313	0.328	0.0342	0.278
(100mm) diameter improvement	0.150	0.569	0.328	0.0468	0.522

Table show the details of pile capacity terms for (10 cm) according to Hansen equation

Case for 10cm length	Pile load by experimental(kN)	Pile load capacity by equation(kN)	Skin friction of pile model with block(kN)	Skin friction of block with surround soil(kN)	Tip load for whole block (kN)
(43 mm) diameter improvement	0.075	0.079	0.218	0.00895	0.07005
(73mm) diameter improvement	0.103	0.201	0.218	0.0152	0.186
(100mm) diameter improvement	0.110	0.369	0.218	0.0208	0.348

The data were used in Hansen equation was as following:

1. value of (Ø) for without improvement case driven for tip $\text{Ø}new = \frac{\text{Ø}+40}{2}$

Ø New =3/4 Ø +10 for skin friction (*berazantzev, 1961) for* the bored case both skin and tip used ($\text{Ø}_{new} = \text{Ø} - 3$)*(berazantzev,**1961**)*

2. for improvement case for tip we used $\text{Ø}new = \frac{\text{Ø}+40}{2}$

For skin friction between soil around and soil compacted surrounds pile (soil block) ($\text{Ø}_{new} = \text{Ø} - 3$) because the friction will decrease because using casing pipe and Ø will increase due to compaction of soil block under tip.

3. because the high increase in value of (C)=92.9Kpa and Ø increase to (59°) the behavior of one block for pile model and compacted soil surrounding it adopted as following example :

Calculating the pile load capacity of improvement diameter (43 mm) for length (15cm)

$$Q_T = \int_0^l P.K_s.\sigma_v.\tan\delta\,.dz + A_b(\sigma_{vb}.N_q)$$

= (2.13*31.285)*1.452*10^{-3}+ (0.15/2*0.561*14.2*tan (59)*(0.15*0.043*π

=0.116 kN

The area was used for tip is for all soil block and this is according to behavior of one block

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